Exhibit A

(selected portions of U.S. Patent Nos. 6,302,212; 6,508,308; 6,581,691 and 6,598,680)

US006302212B1

(12) **United States Patent**
Nobileau

(10) **Patent No.: US 6,302,212 B1**
(45) **Date of Patent: *Oct. 16, 2001**

(54) **TUBING HANGER AND TREE WITH HORIZONTAL FLOW AND ANNULUS PORTS**

(75) Inventor: **Philippe Nobileau**, Nice (FR)

(73) Assignee: **ABB Vetco Gray, Inc.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **09/578,586**

(22) Filed: **Jan. 11, 2000**

Related U.S. Application Data

(63) Continuation of application No. 08/968,392, filed on Nov. 12, 1997, now Pat. No. 6,062,314.

(60) Provisional application No. 60/030,807, filed on Nov. 14, 1996.

(51) **Int. Cl.**[7] **E21B 33/043**

(52) **U.S. Cl.** **166/368**; 166/88.1; 166/88.4

(58) **Field of Search** 166/368, 88.1, 166/88.4, 89.1

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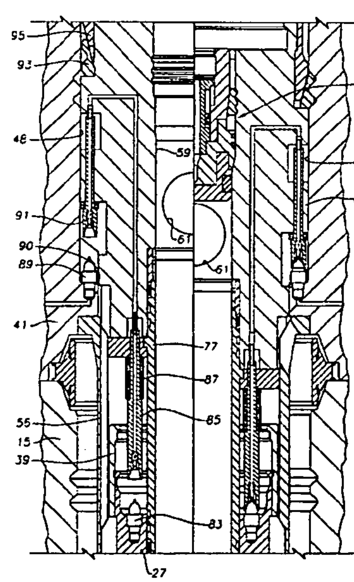
Primary Examiner—William Neuder
(74) *Attorney, Agent, or Firm*—Bracewell & Patterson; James E. Bradley

(57) **ABSTRACT**

A well production assembly includes a production tree which has a lateral production passage extending laterally from a vertical bore of the tree. A tubing hanger, also having a lateral production passage, lands in the tree, with the lateral passages registering with each other. The junction of the lateral passages has flat, tapered sealed areas which mate with one another. An annulus passage extends vertically through the tubing hanger offset from and parallel to the tubing hanger vertical production passage. The annulus passage also has a lateral passage which registers with the lateral passage formed in the tree. The annulus lateral passages have a flat seal area at their junction. The tubing hanger has a downward facing hydraulic connector which registers with an upward facing hydraulic connector located on a shoulder formed in the bore. Once mated, the connectors provide hydraulic or other auxiliary fluid communication to downhole equipment.

20 Claims, 5 Drawing Sheets



TUBING HANGER AND TREE WITH HORIZONTAL FLOW AND ANNULUS PORTS

This application is a Continuation of Ser. No. 08/968,392 filed Nov. 12, 1997 now U.S. Pat. No. 6,062,314, which claims benefit to Provisional 60/030,807 filed Nov. 14, 1996.

TECHNICAL FIELD

This invention relates in general to wellhead equipment, and in particular to a production tree having a tubing hanger therein, the tubing hanger and production tree having lateral production passages.

BACKGROUND ART

A conventional subsea wellhead assembly includes a wellhead housing which supports one or more casing hangers located at upper ends of strings of casing extending into the well. A tubing hanger lands in the wellhead housing above the casing hanger and supports a string of production tubing that extends through the smallest diameter casing. The tubing hanger has a production bore which is offset slightly from the longitudinal axis. An annulus bore also extends through the tubing hanger, parallel to and offset from the axis, for communicating the tubing annulus to above the tubing hanger. The annulus bore is needed during installation of the tubing hanger and tubing to establish circulation down the tubing and back up the annulus. After the well has been completed, a removable plug is installed in the annulus bore, then a production tree is mounted to the wellhead housing. Access through the production tree to the tubing may be made for various workover operations that are needed.

In the last few years, operators have begun installing a different type of wellhead assembly, referred to generally as a horizontal tree. In a horizontal tree, the tubing hanger lands in the tree, not in the wellhead housing located below the tree. The tubing hanger has a lateral flow passage extending from its vertical flow passage. The lateral flow passage registers with a lateral flow passage extending through a sidewall of the tree. Gallery seals are employed to seal the junction between the lateral production passages. The gallery seals comprise seal rings which are coaxial with the vertical axis, with one of the seals located above the lateral passage and the other located below. The lower seal necessarily will be of a smaller diameter than the upper seal in order to provide clearances for installation.

With the horizontal tree, a tubing hanger can be pulled through the horizontal tree without removing the tree. This cannot be done with a conventional tree. While this is an advantage, one disadvantage is the horizontal tree tubing hanger has inadequate room to utilize a vertical annulus passage extending through the a tubing hanger as with a conventional tubing hanger. as Instead, tubing annulus communication is accomplished generally by utilizing a bypass passage through the tree from below the tubing hanger and back into the tree above the tubing hanger. While a bypass passage is workable, it relies on a valve on the exterior for closing the annulus. Some operators believe that a removable plug installed within an annulus passage in a tubing hanger is safer than a valve.

Another disadvantage of a typical horizontal tree tubing hanger has to do with the need to communicate auxiliary fluid to downhole equipment. For example, downhole safety valves are used in a tubing string at some distance below the surface. A safety valve remains open so long as it is supplied with hydraulic fluid pressure. In the absence of fluid

pressure, it will close. Consequently, if the production wellhead assembly is severely damaged, the well would be held under control through the safety valve. In conventional tree tubing hangers, passages are drilled through the tubing hanger from the upper end to the lower end. The upper ends of the hydraulic passages have connectors which mate with connectors on the tree to supply hydraulic fluid. In the horizontal tree, however, this cannot occur because the tubing hanger lands within the tree, not in the wellhead housing below.

Some manufacturers have drilled ports through the sidewall of the tree to communicate with hydraulic passages drilled within the tubing hanger. These manufacturers have employed gallery type seals to seal the junctions of the ports. This again requires a reduction in inner diameter of the bore of the tree. There may be several ports for auxiliary fluid passages, requiring several sets of gallery seals. U.S. Pat. Nos. 5,465,794 and 5,555,935 show ports on the exterior of a tubing hanger that do not requires gallery seals. These ports locate on a spherical surface formed on the tubing hanger and in the bore of the tree.

SUMMARY OF THE INVENTION

In this invention, the tree is of a horizontal type, having a lateral production passage. A tubing hanger, also having a lateral production passage, lands in the tree. The tree has a seal area that surrounds the inlet of the lateral production passages which is flat and inclined relative to the axis. The tubing hanger also has a seal area which is flat and inclined and mates with the tree seal area. The mating flat surfaces obviate the need for gallery seals, allowing a larger bore at that area than in the prior art gallery seal type.

Preferably the tubing hanger has an annulus flow passage that is offset from and parallel to the vertical production passage in the tubing hanger. The vertical annulus passage may be accessed from above and will receive a removable plug after completion. Preferably a lateral passage extends laterally from the vertical annulus passage of the tubing hanger and registers with a lateral annulus passage formed in the tree. The mating openings of the tree annulus passage are on flat and inclined sealed areas formed on the tubing hanger and in the bore of the tree. The lateral annulus passage allows access to the annulus through a valve as an option.

The tree also has an auxiliary passage which extends through a sidewall of the tree and has an auxiliary connector which is located on an upward facing shoulder forming the bore of the tree. The tubing hanger has a downward facing hydraulic connector which telescopingly mates with the connector in the tree bore. The auxiliary passages lead to a downhole safety valve.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. 1A and 1B comprise a vertical sectional view of a wellhead assembly constructed in accordance with this invention.

FIG. 2 is an enlarged partial sectional view of a portion of the wellhead assembly of FIGS. 1A, 1B.

FIG. 3 is a sectional view of a portion of the wellhead assembly of FIGS. 1A, 1B, taken along the line 3—3 of FIG. 2, with the left side showing an installation step and the right side showing the assembly after installation has been completed.

FIG. 4 is a sectional view of the wellhead assembly of FIGS. 1A, 1B, taken along the line 4—4 of FIG. 1.

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(12) **United States Patent**
Shaw

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(54) **PROGRESSIVE PRODUCTION METHODS AND SYSTEM**

(75) Inventor: **Christopher Kempson Shaw**, Claremore, OK (US)

(73) Assignee: **Baker Hughes Incorporated**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 70 days.

(21) Appl. No.: **09/669,385**

(22) Filed: **Sep. 26, 2000**

(51) **Int. Cl.**[7] **E21B 43/00**; E21B 43/12

(52) **U.S. Cl.** **166/313**; 166/68.5; 166/105; 166/242.3; 166/369; 166/375; 166/384; 417/423.3; 417/426

(58) **Field of Search** 166/66.4, 68.5, 166/105, 242.3, 313, 319, 332.1, 369, 370, 375, 384; 417/423.3, 423.5, 424.2, 426

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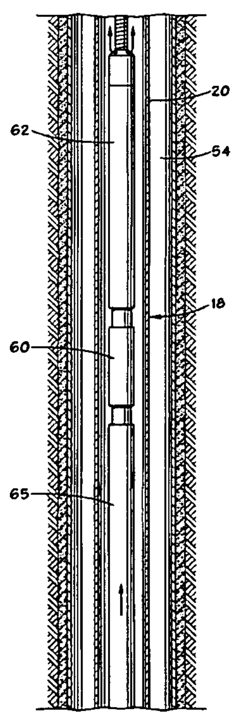
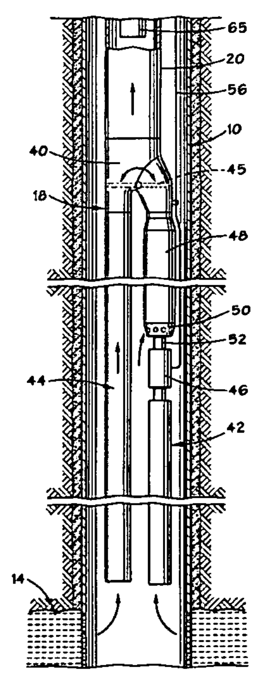
Primary Examiner—George Suchfield
(74) *Attorney, Agent, or Firm*—Bracewell & Patterson, L.L.P.

(57) **ABSTRACT**

Methods for staged production from a wellbore include pumps sequentially operated during the life of the well. In described embodiments, production assemblies are used for progressive staged production process in which the production tubing is bifurcated to provide a pair of legs. One of the legs includes a first pump that may be selectively actuated to flow fluid through one of the legs. Means are also provided, including a sliding sleeve and a flapper valve diverter, for blocking production fluid flow through one leg or the other. A second fluid pump is lowered inside of the production tubing to pump fluid after the first pump has failed.

14 Claims, 7 Drawing Sheets





PROGRESSIVE PRODUCTION METHODS AND SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates in general to oil well electrical submersible pumps. In particular aspects, the invention relates to the use of coiled tubing-disposed pumps for continuing production after a production tubing-disposed pump has failed.

2. Related Art

Electrical submersible pumps ("ESPs") are commonly used in oil and gas wells for producing large volumes of well fluid after natural production has decreased in flow. In conventional methods of production, an ESP would be installed by incorporating it within a string of production tubing or conventional threaded pipe and then lowering the ESP assembly into the well. This process employs the use of a rig and is time consuming. A few ESPs have been installed on coiled tubing for pumping up the annulus surrounding the coiled tubing. Coiled tubing is deployed by a coiled tubing injector from a large reel. There is no need for a rig, and the running time is generally less than for an ESP installed on production tubing. However, because standard wellheads are not designed to receive coiled tubing without first removing the production string, these systems provide no real advantages over traditional systems.

Unfortunately, most ESPs only have a 2 to 3 year life. Thus, at some point in time, a new ESP is needed to continue producing the well. The conventional method to deploy the new ESP is to use a workover rig to remove the production string from the well and replace the worn-out ESP that is incorporated in the string with a new one. The process of removal and replacement costs the well operator both time and money, particularly for offshore subsea wells. Proposals have been made to use a Y-tool with one leg supporting a main ESP and the other a back-up ESP. Improvements to the methods and systems of the prior art are desirable.

SUMMARY OF THE INVENTION

This invention provides systems and methods for staged production from a wellbore. In exemplary embodiments described herein, there may be three progressive stages to the production process. The first stage may be natural production, which uses natural formation pressures to bring the production fluid to the surface. The second stage of production is through the use of a first fluid pump, which may be installed at the time of original well completion on conventional threaded pipe. The third stage is the deployment and use of a second fluid pump on coiled tubing within the production tubing for additional production.

Exemplary production systems are described that allow a well to be progressively produced without the need to remove production tubing from the wellbore. The exemplary systems include a Y-tool with two legs. The Y-tool is suspended at the lower end of a string of production tubing. One of the legs supports a first fluid pump. In one preferred embodiment, there is a diverter assembly incorporated into the Y-tool for selectively isolating flow through either of the legs thereby allowing selective use of the first fluid pump. In an alternative embodiment, a sliding sleeve arrangement provides selective flow through the first fluid pump.

At the point where natural pressure or flow decreases in the reservoir, the first, production tubing-based pump is turned on and operated to failure. Upon failure of the production tubing-based pump, a second fluid pump is run into the production tubing on coiled tubing. Additionally production fluid to the surface is flowed using the second pump, thereby eliminating the need to remove the production tubing from the wellbore and then replace the first fluid pump. Upon failure of the coiled tubing-based pump, that pump may be easily removed from the wellbore and replaced without the cost and time associated with removal of the production tubing from the wellbore.

BRIEF DESCRIPTION OF DRAWINGS

FIGS. 1A and 1B are vertical cross-sectional views illustrating an exemplary wellbore containing a Y-tool with two production tubing legs and configured for well production in stages one and two.

FIGS. 2A, 2B and 2C are side cross-sectional views of the wellbore shown in FIGS. 1A and 1B, shown in a vertical cross-section 90° from FIG. 1A and illustrating the deployment and use of a second ESP on coiled tubing within the first ESPs casing.

FIG. 3 depicts a first alternative embodiment of the invention wherein sliding sleeve assembly is used.

FIG. 4 illustrates a second alternative embodiment of the invention also incorporating a sliding sleeve.

FIG. 5 shows a third alternative embodiment of the invention incorporating sliding sleeve.

BEST MODES FOR CARRYING OUT THE INVENTION

Referring to FIGS. 1A and 1B, there is shown a wellbore 10 that extends downward from a wellhead 12 through rock formations 13 to a hydrocarbon reservoir 14. The wellbore 10 has one or more strings of outer casing (not shown) that are cemented in the wellbore 10. The casing has perforations (not shown) near its lower end allowing flow of well fluid into the wellbore 10 from the earth reservoir 14. A production assembly 18 having a string of production tubing 20 is shown suspended in casing 16. Production tubing 20 is made up of a plurality of tubing sections that are secured together.

As FIG. 1A depicts, the wellhead 12 has a tree 22 that carries a number of valves and fluid passages, as is known in the art. Tree 22 is known as a "horizontal" tree and is commonly installed subsea. A longitudinal bore 24 is defined within the tree 22 and has presents a seating profile 26. The upper end of the tree 22 is sealed by a removable tree cap 28 that fits in bore 24. The tree cap 28 has a removable plug 30, the lower end of which is visible in FIG. 1A. While the cap 28 is shown to be of an internal type, fitting on the upper end of tree 22, it could also be of an external type fitting over the tree 22.

A production tubing hanger 32 is disposed within the tree 22 upon seating profile 26 and is used to suspend the production tubing 20 within the wellbore 10. The tubing hangar 32 defines a vertical passage 34 therethrough. The upper end of the passage 34 carries an annular landing shoulder 36. A removable crown plug 38 is shown seated in the landing shoulder 36. Tubing hanger 32 and tree 22 have mating lateral flow passages 37, 39 for the flow of production fluid.

FIG. 1B illustrates portions of the production assembly 18 within the well 10 below the wellhead. The production tubing 20 is bifurcated at its lower end. A Y-shaped splitter or Y-tool 40 is used to split the production tubing 20 into two separate and parallel legs, a pump leg 42 and a bypass leg

US006581691B1

(12) United States Patent
Jennings et al.

(10) Patent No.: US 6,581,691 B1
(45) Date of Patent: Jun. 24, 2003

(54) LANDING ADAPTER FOR SOFT LANDING A TUBING HANGER IN THE BORE OF A PRODUCTION TREE OR WELLHEAD HOUSING

(75) Inventors: Charles E. Jennings, Houston, TX (US); Norman Brammer, Aberdeen (GB)

(73) Assignee: ABB Vetco Gray Inc., Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 42 days.

(21) Appl. No.: 09/938,881

(22) Filed: Aug. 27, 2001

Related U.S. Application Data

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(51) Int. Cl.[7] E21B 33/043

(52) U.S. Cl. 166/348; 166/75.14; 166/88.1; 166/368

(58) Field of Search 166/348, 368, 166/88.1, 75.14

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Patent Application Filed Aug. 22, 2001 entitled "Running Tool for Soft Land a Tubing Hanger in a Wellhead Housing".

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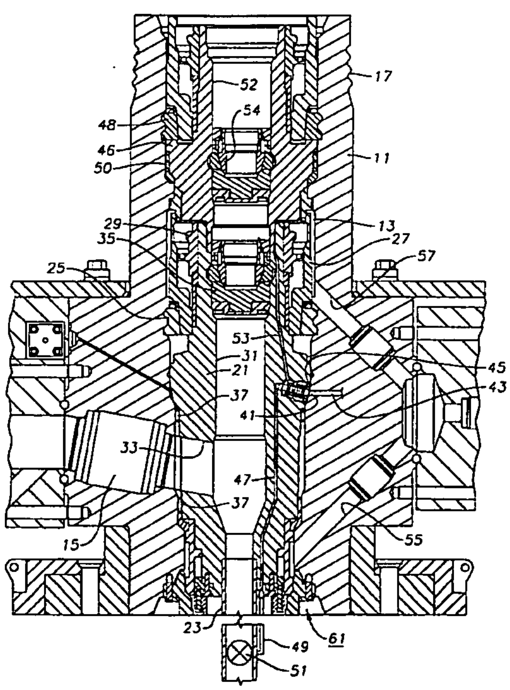
Primary Examiner—Hoang Dang
(74) *Attorney, Agent, or Firm*—Bracewell & Patterson, L.L.P.

(57) ABSTRACT

A landing adapter is used to softly land a tubing hanger in the bore of a production tree. The landing adapter makes initial contact so that the tubing hanger does not have to absorb the harsh impact. The landing adapter has a hydraulic sleeve that strokes axially relative to the tubing hanger. Initially, the sleeve is extended and locked when it is run into the well so that the landing adapter can be hard-landed in the bore. When the sleeve lands in the bore, the impact is absorbed by a landing adapter buffer, not by the tubing hanger. After the hanger with the landing adapter has landed in the bore, hydraulic fluid is bled off so that the tubing hanger gradually descends axially relative to the sleeve and the tree to the retracted position. The landing adapter buffer remains in the tree after the tubing hanger is landed in the bore.

12 Claims, 4 Drawing Sheets



LANDING ADAPTER FOR SOFT LANDING A TUBING HANGER IN THE BORE OF A PRODUCTION TREE OR WELLHEAD HOUSING

This patent application is based upon U.S. provisional patent application Ser. No. 60/232,011, filed Sep. 12, 2000.

TECHNICAL FIELD

This invention relates in general to an improved tubing hanger, and in particular to an improved landing adapter for providing a soft landing for a tubing hanger in the bore of a tree or wellhead housing.

DESCRIPTION OF THE PRIOR ART

Designs for landing tubing hangers in casing hangers for wells in the ocean floor are well known in the prior art. A tubing hanger typically carries or suspends one or more strings of tubing which extend down into the subsea well. Many different tubing hanger designs exist and are the subject of numerous prior art patents. Some of the earlier versions of tubing hangers required a running tool employing a dart for operation that restricted the bore of the tubing hanger. Other designs provide a running tool allowing full bore tubing access during running, while providing means for controlling downhole safety valves during both running and landing operations.

For example, in U.S. Pat. No. 4,067,062, the tubing hanger is lowered into the well and releasably secured to the casing hanger by hydraulic manipulation of the running tool after the tubing hanger has been oriented in the casing hanger. After further hydraulic manipulation, the running tool may be released from the hydraulic set tubing hanger and later run back into the well and reconnected to the tubing hanger for retrieval. Although each of these designs are workable, it is difficult to avoid "hard" landing and possibly damaging the tubing hanger in the well due to the depths at which the subsea wells are typically located. Thus, an improved design for "soft" landing a tubing hanger in a wellhead is needed.

SUMMARY OF THE INVENTION

In one embodiment of the present invention, a tubing hanger with a landing adapter is installed in the bore of a production tree. The landing adapter is permanently mounted on the lower end of the tubing hanger to softly land the tubing hanger. The landing adapter acts as a buffer between the conventional landing shoulder in the bore and a shoulder on the tubing hanger. The landing adapter makes the initial contact with the bore so that the tubing hanger does not have to absorb the harsh impact.

The landing adapter comprises a hydraulically-actuated sleeve that strokes axially relative to the tubing hanger. Initially, the sleeve is extended and locked when it is run into the well so that the landing adapter can be hard-landed in the bore. When the sleeve lands in the bore, the impact is absorbed by the landing adapter buffer, not by the tubing hanger. After the hanger with the landing adapter has landed in the bore, hydraulic fluid is bled off so that the tubing hanger gradually descends axially relative to the sleeve and the tree to the retracted position. The landing adapter buffer remains in the tree and is not retrieved after the tubing hanger is landed in the bore.

BRIEF DESCRIPTION OF DRAWINGS

So that the manner in which the features, advantages and objects of the invention, as well as others which will become apparent, are attained and can be understood in more detail, more particular description of the invention briefly summarized above may be had by reference to the embodiment thereof which is illustrated in the appended drawings, which drawings form a part of this specification. It is to be noted, however, that the drawings illustrate only a preferred embodiment of the invention and is therefore not to be considered limiting of its scope as the invention may admit to other equally effective embodiments.

FIG. 1 is a sectional side view of a horizontal tree having a tubing hanger constructed in accordance with a first embodiment of the invention, with the tubing hanger shown landed in the horizontal tree.

FIG. 2 is an enlarged sectional side view of the left half of a lower end of the horizontal tree and tubing hanger of FIG. 1, with the tubing hanger shown prior to landing.

FIG. 3 is an enlarged sectional side view of the left half of the lower end of the horizontal tree and tubing hanger of FIG. 1, with the tubing hanger shown after landing.

FIG. 4 is an enlarged sectional side view of the left half of a lower end of a horizontal tree and a second embodiment of a tubing hanger constructed in accordance with the invention, with the tubing hanger shown prior to landing.

FIG. 5 is an enlarged sectional side view of the left half of the lower end of the horizontal tree and tubing hanger of FIG. 4, with the tubing hanger shown after landing.

FIG. 6 is an enlarged sectional side view of the left half of a lower end of a horizontal tree and a third embodiment of a tubing hanger constructed in accordance with the invention, with the tubing hanger shown prior to landing.

FIG. 7 is an enlarged sectional side view of the left half of the lower end of the horizontal tree and tubing hanger of FIG. 6, with the tubing hanger shown after landing.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT OF THE INVENTION

Referring to FIG. 1, a production tree 11 is of a type known as a "horizontal tree." Although production tree 11 is depicted as a horizontal tree, it could also be a conventional tree (not shown), wherein the tubing hanger would go in the wellhead below the tree. Production tree 11 lands on a wellhead housing, typically located on the sea floor. Production tree 11 has a vertical bore 13 extending through it. A lateral passage 15 extends from bore 13 for the flow of production fluid. Production tree 11 has a groove profile 17 on its exterior upper end for connection to a rise (not shown) while lowering the tree 11 to the sea floor and during completion operations. After installation is complete, a cover (not shown) will be placed over the upper end of production tree 11.

A tubing hanger 21 lands in bore 13 of production tree 11. Tubing hanger 21 supports a string of tubing 23 that extends into the well for the flow of production fluid. Tubing hanger 21 is secured in bore 13 by a plurality of dog segments 25. A cam or lower sleeve 27, when moved axially downward, pushes dog segments 25 outward into a profile in bore 13. A collar 29 on the upper end of tubing hanger 21 is used for engaging tubing hanger 21 while lowering it into tree 11.

Tubing hanger 21 has an axial passage 31 and a lateral passage 33 extending therefrom that is rotationally oriented and axially aligned with production tree lateral passage 15. A wireline plug 35 is installed in axial passage 31 above lateral passage 33 to cause production fluid flow to flow out lateral passage 33. Circumferential seals 37 locate above and below lateral passage 33.

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DeBerry

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(45) Date of Patent: Jul. 29, 2003

(54) SUBSEA WELLHEAD EQUIPMENT

(75) Inventor: Blake T. DeBerry, Singapore (SG)

(73) Assignee: Dril-Quip, Inc., Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(22) Filed: Jun. 24, 2002

(65) **Prior Publication Data**

US 2003/0019631 A1 Jan. 30, 2003

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(51) Int. Cl.[7] E21B 29/12; E21B 19/00

(52) U.S. Cl. 166/368; 166/348; 166/88.4; 166/86.1

(58) Field of Search 166/348, 368, 166/86.1, 88.4

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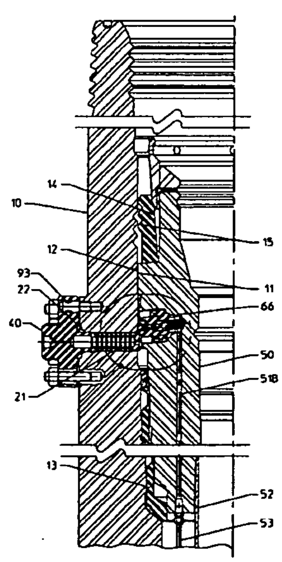
Primary Examiner—Thomas B. Will
Assistant Examiner—Thomas A. Beach
(74) *Attorney, Agent, or Firm*—Loren G. Helmreich; Browning Bushman, P.C.

(57) **ABSTRACT**

A wellhead apparatus which includes a spool for use in a horizontal tree and having a vertical bore therethrough, and a tubing hanger adapted to be lowered into and landed within the bore of the spool to suspend a tubing string on the lower end of the tubing hanger within the wellbore. The spool has a radial opening therethrough to receive a bellows which forms a fluid passageway removably mounted within the opening by means of a flange on the outer end of the bellows releasably connected to the outer side of the spool. The tubing hanger has an opening therethrough which includes a lateral portion connecting with its outer diameter and a vertical portion leading to a pressure responsive operator for a tubing safety valve. The passageways have seal surfaces on their opposing ends, and the end of the stem is engaged by the seal surface of the bellows to open the poppet as the hanger is lowered. An insert within the lateral portion of the hanger opening has a bore which forms a fluid passageway adapted to be opened and closed by a poppet valve mounted on a stem.

17 Claims, 9 Drawing Sheets



SUBSEA WELLHEAD EQUIPMENT

REFERENCE TO PROVISIONAL APPLICATION

This application claims the benefit of Provisional Application Serial No. 60/300,889 filed Jun. 25, 2001, and entitled "Subsea Wellhead Equipment".

BACKGROUND OF THE INVENTION

This invention relates generally to wellhead equipment, including a so-called "horizontal tree", for use in the drilling and completion of a subsea well.

As compared with a conventional Christmas tree, a horizontal tree includes a spool connected to the upper end of the wellhead housing and having a bore in which a tubing hanger may be landed for suspending a tubing string within the well. The spool has ports with valves to control the flow of hydrocarbons through the tubing and tubing/casing annulus, as well as to permit workover of the well, as in conventional equipment, despite plugs removable installed in its bore above the hanger. Upon removal of the plug, the tubing hanger may be removed through a blowout preventer (BOP) mounted above the spool, without requiring removal of the tree, thus providing a significant advantage for wells where there is a risk of having to pull the tubing.

In wellhead equipment of this type, hydraulic control fluid is supplied from a remote source to a downhole function, such as the fluid responsive operator for a subsurface safety valve (SSSV) which is carried by the tubing string to normally maintain the tubing open but close it in response to emergency conditions by reduction of the hydraulic fluid pressure on the operator. In such equipment, hydraulic fluid is adapted to be supplied to the operator from a source at the surface through fluid passageways in the spool and hanger whose sealing surfaces are adapted to be aligned and sealed with respect to one another to fluidly connect them when the hanger is oriented into a landed position in the spool bore. This type of equipment has become known in the art as a "penetrator", presumably by virtue of the ability to penetrate the tubing hanger leading to the SSSV. See, for example, U.S. Pat. Nos. 5,465,794, 5,555,935, 5,865,250, 6,119,773, 6,244,348 B1 to ABB Vetco.

In at least one of these patents, the fluid passageway in the hanger includes an insert installed in an opening in the hanger connecting with its bore and having a normally closed poppet valve which may be opened to permit the hydraulic fluid to be supplied through an adaptor to the SSSV operator, in order to open the tubing. The poppet valve is then permitted to close as the SSSV is maintained open. Pressure fluid is exhausted from the operator to permit the valve to close in the event of an emergency.

More particularly, the inner end of a stem on which the poppet valve is mounted protrudes from the seal surface of the fluid passageway in the hanger to engage the seal surface of the spool, and thus be moved to open position, as the hanger is lowered into landed position. This permits fluid from the remote source to urge the operator of the SSSV to open position.

In the case of penetrators made pursuant to such patents, the sealing surface about the opening in the spool or the sealing is formed on a spherical surface in the bore of the spool, which is understandably difficult to form and refinish in the event of damage.

In the penetrator shown in U.S. Pat. No. 5,582,438, to Kvaerner Oil Field Products, and other patents based thereon, the fluid passageway in the hanger is formed on the end of a tubular body received in a carrier which is initially spaced from the spool bore, as the hanger is lowered into the spool bore, and then cammed inwardly to cause a seal surface on its end to engage a seal surface within the bore of the spool. Among other things, the mechanism by which the body is moved to sealing position requires a large number of moving parts.

In each of these prior penetrators, the hanger and spool are provided with parts for orienting their seal surfaces into axially aligned position. However, there is the possibility that the seal surfaces on the hanger and spool may not be sufficiently axially misaligned, when landed, as to prevent leakage between the hanger and spool.

It is the primary object of this invention to provide a penetrator of this type which, in its preferred and illustrated embodiment, overcomes one or more, and preferably all, of these problems and further which has other distinct advantages over the prior art penetrators.

In accordance with the illustrated and preferred embodiment of the present invention, the tubular body of the insert in the fluid passageway of the hanger has a spherical surface at one end, and a seat ring releasably held on the inner end of the body mounted on the inner end of the body has a matching sealing surface for swiveling within the spherical surface in the insert, as ports through the insert and seat ring are maintained in fluid communication. A seal ring surrounds one end of the port in the seal surface, and another seal ring surrounds the other end of the port in the spherical end of the seat ring for sealing with respect to the spherically shaped end of the insert body to maintain a seal between the surfaces despite minor axially alignment.

In accordance with another novel aspect of the invention, the axes of the fluid passageways in the spool and hanger extend at an acute angle with respect to one another, and the flat seal surfaces on them are disposed within parallel planes which extend at vertical angles perpendicular to the axes of the passageways. More particularly, one of the seal surfaces is resiliently urged to a position in which it is engaged by and then cammed inwardly by the other seal surface as the hanger is lowered therepast.

In the illustrated and preferred embodiment of the invention, the seal surface on the end of the fluid passageway of the spool comprises a bellows which extends within the spool opening and has its outer end carried by a flange releasably attached to the outer side of the spool. Thus, the bellows is removable from the spool opening for replacement or repair of its sealing surface on its inner end upon disconnection of the flange from the outer side of the hanger.

As illustrated and described, the seal surface of the bellows has a seal surface which extends from the spool opening into a position to be engaged by and cammed outwardly by the seal surface of the hanger. More particularly, the spool opening has an inwardly facing shoulder, and the bellows has an outwardly facing shoulder to position the seal surface to be engaged and cammed outwardly as the seal surface on the hanger slides downwardly over the seal surface on the bellows.

In the drawings, wherein like reference characters are used throughout to designate like parts:

FIG. 1 is a half vertical sectional view of the wellhead assembly during lowering of the tubing hanger into a landed position within the bore of the spool;

FIG. 1A is an enlarged detail view of the portions of the inner end of the bellows and insert indicated at 1A in FIG. 1, as the insert first engages the bellows for sliding over the seal surface on its inner end;